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Scenario Analysis of a Municipality's Food Purchase to Simultaneously Improve Nutritional Quality and Lower Carbon Emission for Child-Care Centers

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Abstract: Public procurement has been highlighted as an important strategic tool to drive sustainable development. The present study aimed at providing direction for decreasing greenhouse gas emissions (GHGE) by 25% for the food purchased by child-care centers in the City of Copenhagen while simultaneously providing nutritionally adequate, affordable and tasty menus. Baseline data were provided by compiling food purchase data with datasets matching each food item to a proxy food item and further with databases containing nutrient and GHGE information. For each food item, the edible amount was estimated in order to evaluate nutritional content and GHGE per 10 MJ. Two scenarios were modeled, i.e., a plant-rich diet and a lacto-ovo vegetarian diet directed at children two to five years old based on current purchase practice. Finally, the diets were translated into guidelines for menu planning. Amounts of pulses, nuts and seeds, as well as dark green vegetables and plant-based fats, were increased substantially in the two scenarios, while animal fat was decreased and the amount of meat was either reduced or eliminated in the plant-rich and lacto-ovo vegetarian diets, respectively. These kinds of changes in public food procurement have the power to significantly affect the transition toward a more healthy and sustainable food system.

Keywords: food service; guidelines; sustainable and healthy food; sustainable cities; lacto-ovo vegetarian diet; plant-rich diet

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1. Introduction

The current Western food consumption pattern is unsustainable from both a health and environmental point of view [1]. The global food system, which encompasses production, processing, packaging, distribution, consumption and waste of food is currently responsible for about 25–30% of total human-made greenhouse gas emissions (GHGE) [2] as well as other environmental concerns including substantial biodiversity loss [3]. In order to achieve a more sustainable food system, the entire food chain must be considered from farm to fork. It is also clear that the desired transition toward sustainable food consumption will not happen without a shift in people's diets [1]. Consequently, several countries have incorporated sustainability of diets into their food-based dietary guidelines (FBDG), e.g., Sweden [4], Germany [5], UK [6] and the Netherlands [7]. In Denmark, a nationally adapted healthy plant-rich diet based on the global EAT-Lancet reference diet has been developed [8], providing the direction for the newly launched revision of climate-friendly FBDG in Denmark [9]. Public procurement has been highlighted as an important strategic tool to drive sustainability development [10]. This includes the public purchases of food products and catering services, including food served in schools, child-care centers for children aged zero to six years and nursing homes. The large volume of public meals served increases the need to seek relevant environmentally sustainable practices for the food procurement [11]. The EAT-Lancet Commission states that chefs and other culinary professionals are well positioned to make healthy and sustainable foods delicious by applying unique insights, skills and creativity to craft next-generation models of innovation in food service [12].

An example of a global initiative, pushing for a more climate-friendly food system, is the Cool Food Pledge, developed by the World Resources Institute (WRI), which facilitates a platform aiming at helping dining facilities lower food-related GHGE by 25% by 2030 [13]. They offer a calculator intended to (roughly) measure and monitor over a period of time GHGE impacts of the food purchased. The calculator uses life cycle assessment data from Poore and Nemecek [14] and carbon opportunity cost data from Searchinger et al. [15]. In addition, the nutritional content of the food should be monitored to ensure that the nutritional needs of users of the public catering service are not compromised because of a conversion toward the purchase of food that is more sustainable but rather result in meal compositions more in line with recommendations.

A barrier to achieving a more sustainable public procurement is the potential additional cost and the budget constraints practitioners in public organizations experience. In Denmark, the additional costs of the conversion toward increased use of organic products in public kitchens have been largely covered by using less processed food products, buying local and seasonal food products and reducing food waste [16,17]. In the City of Copenhagen, 84% of food served in public kitchens in 2019 was estimated to be organic (93% in child-care centers) [18]. To achieve this, the municipality has focused on vocational training and upskilling of the food professionals with the help of consultants. In 2019, the City of Copenhagen launched a new food strategy, setting targets for how the city will further work to ensure healthy, organic and sustainable meals. The strategy sets a target to reduce GHGE from public meals by 25% by 2025 relative to 2018, taking into account nutritional requirements and culinary considerations while keeping the share of organic food purchase at target level [19]. It is suggested that one way to reach the target of the climate impact reduction is to serve more plant-rich meals, as well as to substitute some meat with other types of meat with less climate impact. The first step should be to make guidelines for the municipality's child-care centers, taking the food- and health-based recommendations of the Danish Veterinary and Food Administration in "Guide to healthier food in the child-care centers" into consideration [20].

To make informed decisions about how to best promote environmental sustainability in public kitchens, quantification of current environmental impacts is important, as well as knowledge on different scenarios for reducing, e.g., GHGE, while at the same time meeting the nutritional requirements of the final users and the economic constraints of the public kitchens. Appropriate food composition and climate impact databases, as well as food matching procedures, are critical to obtain high-quality estimations of nutrient intake and climate impact. This is a challenge, as general computer-assisted food matching tools are not available, although highly needed [21,22]. A test combining food intake data and food composition data from four countries showed that proper food group classification is essential for the quality of computer-assisted food matching [22]. In addition, food group classification should offer the potential to investigate a variety of specific research questions including processing and plant/animal origin [23].

Höijer et al. stated that there is an urgent need for research within all public meal arenas, between which conditions and challenges may vary, according to issues of health and sustainability [24]. So far, research involving sustainable nutrition in food service is scarce [25].

The main aims of the present study were to provide baseline data on the food and nutritional content and climate impact of food purchased by child-care centers in the City of Copenhagen and to investigate two scenarios to reduce the climate impact while ensuring nutritional adequacy. One scenario was a plant-rich diet based on the Danish adapted healthy plant-rich diet and one was a lacto-ovo vegetarian diet, as some families may request vegetarian meals for their children. Finally, the study aimed to convert the diets into main guidelines and practical application in menu planning, i.e., rules of thumb for frequency of serving over a week.

2. Materials and Methods

2.1. Data Compiling

Figure 1 illustrates the method for data compiling. Three overall datasets were combined using Excel Power Pivot, i.e., food purchase data over a year, food matching datasets connecting each food item to a proxy food item and to information on edible amounts and finally food databases containing nutrient and environmental impact information on the proxy foods.

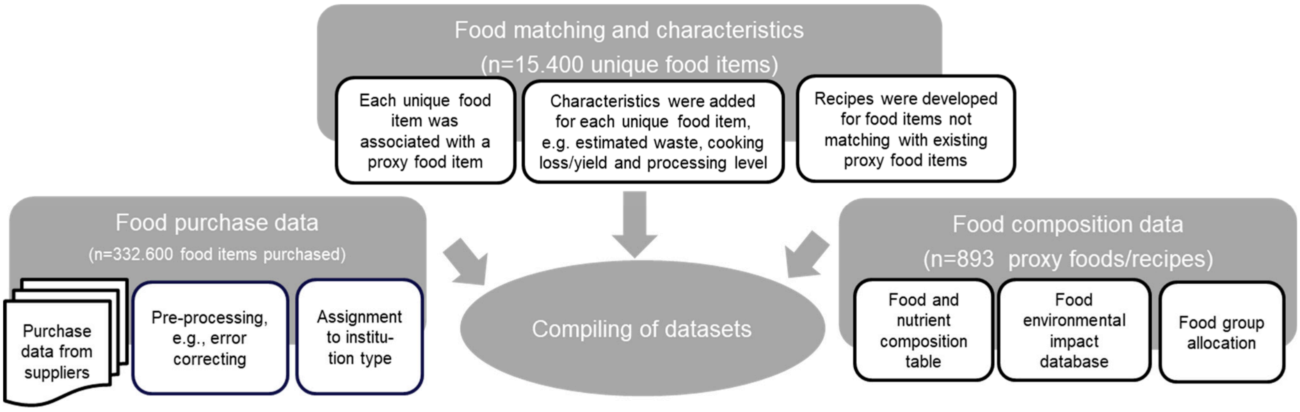

Figure 1. Method for data compiling based on three overall datasets for the total food purchased by the municipality.

2.1.1. Food Purchase Data

The City of Copenhagen provided data for food purchases for the year 2018 for all public kitchens, including child-care centers for children aged 0–6 years. Data were gathered from the main wholesale food supplier on amounts of foods bought in kilograms (kg), their price per kg and information on organic declaration. Smaller suppliers offering mainly one food category (e.g., fish or fruits) were also included, whereas smaller suppliers providing a variety of food categories were excluded in order to simplify the calculations. The dataset was estimated to comprise 88% of the total food purchase calculated based on the price. This was evaluated to be representative of the full purchase to a reasonable degree, i.e., not skewed toward certain specific food categories. Errors were corrected, e.g., weight estimates were calculated and imputed where missing. Further, information on institution type, i.e., child-care centers, was added to the dataset.

2.1.2. Food Characteristics and Matching

Characteristics of each unique food item (different item numbers) were added with regard to edible proportion (estimated unavoidable food waste excluding bones, peels, glazing, etc.) and weight change factor at cooking, depending on processing level (i.e., raw or cooked). According to Colombo et al. [26], it was estimated that only about 20% of the salt applied to cooking water ends up in consumed food such as pasta (Supplementary Table S1). Further, each unique food item was associated with a proxy food item, i.e., the best matching food in the food and nutrient composition table [27]. When a good food match could not be found, data from similar foods, data from the product label or recipe data for multiple ingredient foods were used.

The food items were categorized into the following food groups: starch-rich foods; fruits; vegetables; plant-based protein-rich foods; meat; egg; fish and seafood; dairy products; plant-based beverages (dairy alternatives); animal- and plant-based fats; discretionary foods and beverages; and condiments and seasoning. These groups were further divided into subgroups according to their nutritional or climate impact properties, e.g., different grain and vegetable types, etc. For details and examples of foods included in the food groups, see Supplementary Table S1.

2.1.3. Food Composition Data and Climate Data

Nutritional composition data of the proxy foods were obtained from The Danish Food Database [27]. The data were updated with newer analysis not yet incorporated into the database (i.e., the nutritional content of salmon, several cereals, seeds and nuts [28,29]) and checked and updated for missing data on added sugar and micronutrients. Missing data were sourced from the Swedish Food database [30] or estimated from similar products where appropriate.

Climate impact was obtained from the Cool Food Pledge food purchasing tracking sheet [13] with few adjustments (see Supplementary Table S1). These data include default weighted European average data for GHGE by food type from total agricultural supply chains, i.e., from feed, farm, processing, transport, packaging and losses to point of purchase (Metric 2). Data also include global average data for carbon opportunity costs (Metric 4) due to the assumption that changes in food demand (whether an increase or decrease) will affect agricultural land demand at the global level, e.g., the amount of carbon that could be stored if production of that food declined and land in agriculture returned to its native vegetation [31]. Calculations of climate impact take into account food waste due to bones in meat and fish (boneless equivalent).

In addition, each food item was assigned to relevant food groups and subgroups. The food groups and subgroups were defined to include all main foods based on their significance from either a climate reduction or a nutritional perspective. Supplementary Table S1 includes information on procurement food items included in the food groups.

2.2. Scenario Modelling

To estimate the potential for change in food purchase to reduce climate impact, a plant-rich diet based on the Danish adapted healthy plant-rich diet for people aged 6–65 y [8] was modeled. The Danish adapted healthy plant-rich diet 6–65 y was developed based on the EAT-Lancet Commission's reference diet and in accordance with the Danish FBDG and a few updates [8]. In addition, a lacto-ovo vegetarian diet including eggs and dairy products but eliminating meat, poultry, fish and seafood was modeled.

Both diets were modified to fit nutritional requirements of children aged 2–5 y [32] according to the Nordic Nutrition Recommendation (NNR) age-adapted nutrient density (per 10 MJ), e.g., more dairy products were included compared with the Danish adapted healthy plant-rich diet 6–65 y to account for the increased calcium requirements for small children. The recommended nutrient density and the recommended macronutrient composition for planning diets for groups (E%) were used as reference intakes. It is assumed that the meals of a day at a child-care center on average reflect the diet composition of a whole day, except for lower amounts of discretionary foods. The meals at the child-care centers include breakfast for a small proportion of the children as well as lunch meals and 1–2 in-between meals for most children (morning snack and afternoon snack). Further, the diets were adapted to be closer to the baseline purchase pattern to minimize the changes required and in order to keep estimated costs within max +5% compared with the baseline.

Microsoft Excel spreadsheets were used to construct the scenarios and calculate the nutritional content, climate impact and costs of the modeled diets, with total energy intake adjusted to 10 MJ. The modeling was based on the constructed food groups and subgroups as described in Section 2.1.3, with the number and proportion of individual foods within each food group and subgroup reflecting the current food purchased for child-care centers and the institutions' habitual use of food items.

Finally, the effect of an estimated cooking loss of vitamins (10%) and minerals (2.5%) was evaluated for critical vitamins as described by Lassen et al. [8].

2.3. Conversions to Cooked Amounts per Week per Child and Guidelines for Menu Planning

In order to bring the results into practical application and guidelines for menu planning, quantities per 10 MJ were converted to cooked quantities for a 2- and 4-year-old over a week and from here to frequency of serving over a week and guidelines. The continued ability to create tasty meals as well as the comprehensibility and feasibility of the plant-rich guidelines for menu planning were tested in a small pilot study among five child-care centers (not reported here). It was estimated that the children get about 45% of their daily energy intake at the child-care centers, including approximately 23% from lunch meals (not including beverages) and 15% from a larger snack meal, e.g., in afternoon, and 7% from breakfast/morning snacks and beverages [33]. This means that an average 2-year-old child receives 1.935 MJ and an average 4-year-old child receives 2.565 MJ per day at the child-care centers.

3. Results

3.1. Background Information

The dataset for the total food purchased by the municipality consisted of 332,600 records. Forty-seven percent of these were from child-care centers, corresponding to close to three thousand tons of food. This amount is distributed to 362 delivery locations. Share of organic food procurement (percentage of weight) using the dataset from 2018 was 87%. Organic Cuisine Label calculation might result in a higher organic food share, as marine fish that are not from aquaculture are to be considered neutral in the organic calculations [34].

3.2. Food Group Contents

Table 1 summarizes the amounts of foods at baseline and in the two scenarios. Compared with baseline, the plant-rich diet scenario contained lower amounts of beef/lamb and pork (−62% and −38%, respectively) in order to lower climate impact. The plant-rich diet contained roughly similar amounts of cheese and poultry (+7% and −6%, respectively) as found at baseline but higher amounts of egg (+46%). The amount of egg was increased relatively more than poultry to reduce both costs and climate impact. The amount of liquid milk was increased to meet dietary recommendations for calcium (+19%), while on the other hand, a lower amount of other dairy foods (−33%) was included in order to reduce costs and climate impact. The amount of fish was increased according to the Danish FBDG (+34%). The distribution of types of seafood (fish and shellfish) was changed toward seafood that has been found to have lower climate impact, e.g., from 12% to 5% high-climate impact seafood (e.g., shrimp) and from 19% to 40% low-climate impact seafood (e.g., mackerel and herring) (not shown). In the lacto-ovo vegetarian diet, neither meat nor fish products were included, but eggs were increased more than threefold compared with the baseline, and cheese was increased by 60% to meet dietary recommendations for protein and micronutrients.

The amounts of plant-based protein-rich foods were increased substantially in the plant-rich diet, both to provide protein and to provide sufficient amounts of micronutrients. Pulses were increased by a threefold to 41 g per 10 MJ and nuts and seeds were increased by a little more than a fourfold compared with the baseline with relatively more ground nuts/peanuts in order to keep costs down. Although these levels of food products are much higher compared with the baseline, it is still reduced compared to the Danish adapted plant-rich diet [8] and Danish FBDG for daily intake of nuts [9]. This was done in order to keep costs down and to match baseline intake better in the plant-rich diet. In addition, for this age group, nuts must be crushed or ground, making it more challenging for the kitchen workers to use them as snacks, etc. In the lacto-ovo vegetarian diet, seeds and nuts were further increased to match Danish FBDG. Moreover, processed plant-based protein-rich foods were added to the diet to add variation, including processed soy-based products such as tofu.

Table 1. Content of foods at baseline per 10 MJ (edible amounts) based on the municipality's purchase data for child-care centers (baseline) and in two scenarios: a plant-rich diet and a lacto-ovo vegetarian diet.

Food Groups	Baseline (g per 10 MJ)	Scenario 1: Plant-Rich Diet 2–5 y (g per 10 MJ)	Scenario 2: Lacto-Ovo Vegetarian Diet 2–5 y (g per 10 MJ)
Bread and cereals [1] (% whole-grain products)	335 (59% whole-grain)	280 (54% whole-grain)	281 (57% whole-grain)
Potatoes	100	100	100
Vegetables total [2]	235	275	275
–Dark green	10	75	75
–Red and orange	113	100	100
–Green peas	9	9	9
–Other vegetables	103	91	91
Mushrooms	3	3	30 [12]
Pulses [3]	13 (10 g dried)	41 (30 g dried)	41 (30 g dried)
Processed plant-based protein-rich foods [4]	1	0	23
Tree and ground nuts	1	15	30
Seeds [11]	4	9	18
Fruit total [5]	173	275	275
Dry fruit	8	2	2
Milk	307	364	346
Dairy foods [6]	54	36	54
Cheese	19	20	30
Beef and lamb [7,8]	25	9.5	0
Pork [8]	15	9.5	0
Poultry [8]	30	28	0
Egg	16	23	60
Fish, total [8,9]	47	63	0
Fats [10], plant-based	37	46	32
Fats [10], animal-based	28	4	4
Coffee and tea	3	3	3
Discretionary foods and beverages	26	26	26
Condiments and seasoning	15	15	15

[1] Combination of bread and grains; [2] Includes green peas but not pulses and mushrooms; [3] Combination of dried and processed and cooked pulses (conversion to dried amount shown in parenthesis); [4] Processed plant-based, protein-rich foods consist of 63% tofu or other soy-based products, 15% Quorn and the rest other products; [5] Includes fruit, berries and juice (limited amount) but not dried fruit; [6] Not including milk and cheese; [7] Includes small amount of beef in mixed beef and pork products; [8] Includes predominantly raw meat; [9] Different proportion of low/middle/high-climate-impact fish included; [10] Includes fatty products, such as fatty sauces and dressings; [11] In addition, the bread purchased contains 5–7 g seeds; [12] Mushrooms should be processed/cooked as they contain smaller amounts of phenylhydrazines (not found in, e.g., oyster mushrooms [35]) than raw mushrooms [36].

Amounts of bread and cereals were decreased in order to adjust total energy intake levels to 10 MJ. The relative amount of whole-grain products was roughly the same in both scenarios compared with the baseline (59%, 54% and 57% for the plant-rich diet and the lacto-ovo vegetarian diet, respectively) as the dietary fiber content was well above the minimum recommended level already at baseline. However, small changes in the types of grains were made; i.e., more oat products (from 16 g to 30 and 44 g per 10 MJ, respectively, for Scenario 1 and Scenario 2) and less rice (from 22 g to 15 g rice per 10 MJ in Scenario 1 and Scenario 2, respectively) (not shown). Moreover, the use of quinoa was increased in Scenario 2 (lacto-ovo vegetarian diet) to 8 g per 10 MJ. The total amount of fruit and vegetables was increased in both scenarios compared with the baseline by 34%: from 408 g/10 MJ to 550 g/10 MJ (625 g/10 MJ including cooked pulses). In order to change the diet as little as possible and keep costs down, the amount was not increased further to 600 g/10 MJ excluding pulses, as was done in the Danish adapted healthy plant-rich diet [8]. The amount of fruit was especially increased and also dark green vegetables were increased to provide more, e.g., iron and calcium. Additionally, the amount of mushrooms was increased in the lacto-ovo vegetarian diet because of, e.g., their aroma properties.

Content of animal fat was substantially decreased. The content of plant-based fats was not increased by the same amount because of the increase in nuts and seeds, which are rich in fat. Baseline contents of discretionary foods and drinks (equivalent to 340 kJ/10 MJ), condiments and seasoning as well as coffee and tea (equivalent to 64 kJ/10 MJ) were kept on the same level in both scenarios.

3.3. Nutrient Contents

Table 2 shows that at baseline the percentage of energy (E%) from fat was 35 and therefore a little higher compared with the recommended range of 32–33 E% for planning diets. Energy from saturated fat was above the recommended <10 E% (13 E%). On the other hand, the E% from protein was slightly lower. For the two modeled scenarios, the recommended macronutrient distribution was obtained.

Table 2. Content of nutrients at baseline based on a municipalities procurement data for child-care centers and in two scenarios: a plant-rich and a lacto-ovo vegetarian diet, compared to recommended nutrient densities.

Nutrients [1]	Baseline (per 10 MJ)	Scenario 1: Plant-Rich Diet 2–5 y (per 10 MJ)	Scenario 2: Lacto-Ovo Vegetarian Diet 2–5 y (per 10 MJ)	NNR Recommended Nutrient Density [2]
Protein, total, g	78	88	86	
Protein, total, E%	13	15	15	10–20 (15)
Carbohydrates, g	289	290	291	
Carbohydrates, E%	52	53	53	45–60 (52–53)
Added sugar, E%	3	3	3	≤10
Fat total, g	93	88	88	
Fat total, E%	35	33	33	25–40 (32–33)
Saturated fatty acids, E%	13	9	9	≤10
n-3 fatty acids, E%	1.3	1.5	1.1	≥1
Dietary fiber, g	39	41	45	≥20
Vitamin A, RE	1277	1021	841	660
Vitamin D, µg	3	4	2	19
Vitamin E, α -TE	13	17	18	9
Thiamine, mg	1.5	1.7	1.7	1.1
Riboflavin, mg	1.6	1.8	2.0	1.3
Niacin, NE	25	29	28	17
Vitamin B6, mg	2.3	2.1	2.0	1.3
Folate, µg	490	655	712	151

Table 2. *Cont.*

Nutrients [1]	Baseline (per 10 MJ)	Scenario 1: Plant-Rich Diet 2–5 y (per 10 MJ)	Scenario 2: Lacto-Ovo Vegetarian Diet 2–5 y (per 10 MJ)	NNR Recommended Nutrient Density [2]
Vitamin B12, µg	6.2	6.6	2.7	1.5
Vitamin C, mg	140	201	197	57
Sodium, mg	2585	2299	1988	≤2400 [3]
Potassium, mg	3433	3981	4067	3396
Calcium, mg	1000 [3]	1157 [3]	1289 [3]	1132
Magnesium, mg	375	449	545	226
Phosphorus, mg	1610	1785	1956	887
Iron, mg	13	15	16	15
Zinc, mg	11	11	12	11
Iodine, µg	166	171	131	170
Selenium, µg	47	55	47	47

[1] Vitamin and mineral loss due to cooking is not subtracted, [2] Recommended nutrient density (per 10 MJ) to be used for planning diets for groups of individuals (2–5 years) calculated from Nordic Nutrition Recommendations (NNR) [37], [3] An estimated amount of 136 mg calcium from 1.13 L water per 10 MJ was added.

For most micronutrients, the observed density at baseline well exceeded the recommendation, meaning the content per 10 MJ was adequate. For potassium, zinc and selenium, the observed density just met the recommendation, and for iodine, the density was just below the recommended value. The nutrients with a lower mean observed density than recommended included vitamin D, calcium and iron: −84%, −12% (incl. calcium from water) and −13% of the recommended value, respectively.

For the two modeled scenarios, vitamin D content was, likewise, very low compared with recommended intake, especially in the lacto-ovo vegetarian diet due to the elimination of fish. This also affects iodine content, which was found to be below recommendation in the lacto-ovo vegetarian diet (Scenario 2). Iron, zinc and selenium were just over or at the recommended level in Scenario 2.

3.4. Climate Reduction Potential

Table 3 shows that about 22% of GHGE estimated from total agricultural supply chains (Metric 2) can be saved by switching to the plant-rich diet, while the reduction is 36% by switching to the lacto-ovo vegetarian diet. Reductions are greater when including potential carbon opportunity costs (COC) (Metric 2 + 4): 27% and 42%, respectively.

Table 3. Estimated GHGE from total agricultural supply chains and combined total agricultural supply chains and carbon opportunity costs (COC), based on WRI values (Metric 2 and Metric 2 + 4, respectively) [13] at the baseline purchase and for Scenario 1 and Scenario 2, respectively.

Metrics	Baseline (per 10 MJ)	Scenario 1: Plant-Rich Diet 2–5 y (per 10 MJ)	Scenario 2: Lacto-Ovo Vegetarian Diet 2–5 y (per 10 MJ)
GHGE (Metric 2) (kg CO_2-e)	4.3	3.3 (−22%)	2.7 (−36%)
GHGE inclusive COC (Metric 2 + 4) (kg CO_2-e)	17.5	12.8 (−27%)	10.1 (−42%)

3.5. Guidelines for Menu Planning

Table 4 shows the main guidelines for menu planning, including suggestions for frequency of serving over a week (5 days) based on calculated average weekly cooked amounts. Based on the pilot study, the wording and the structure of the final guidelines were simplified and made easier to comprehend, but the overall messages remained the same. For the plant-rich diet, lunch dishes with meat should be served once a week (besides once a week for snack meals) and dishes with fish should be served minimum once a week for lunch (besides once a week for snack meals). Further, pulses should be served as the main protein component for lunch about twice a week for both the plant-rich diet and the lacto-ovo vegetarian diet. In addition, as part of the lacto-ovo vegetarian diet, processed protein-rich plant-based foods (or alternatively pulses) should be served in one meal per week and eggs twice a week for lunch or a snack meal (once a week or every second week for the plant-rich diet). Nuts and seeds should be served frequently as part of both diets—e.g., moderate portion sizes on a daily basis—and additionally at least twice a week in the lacto-ovo vegetarian diet or in slightly larger portion sizes.

Table 4. Guidelines for menu planning, serving frequency and average cooked, edible amounts per week per child at the child-care center, for 2 y (1.9 MJ/d) and 4 y (2.6 MJ/d), respectively, for the plant-rich diet, as well as special considerations for the lacto-ovo vegetarian diet.

Main Guidelines	Frequency of Serving (Plant-Rich Diet) [1]	Average Weekly Serving Amounts at the Child-Care Center per Child (2–4 y) [2]	Additional Considerations for Lacto-Ovo Vegetarian Diet
1. Serve vegetables/fruits in all meals and in many colors	Serve fruits and vegetables in all meals including both dark green and red-orange vegetables several times a week (both lunch meals and snack meals).	Min. 550–700 g	Additionally, small amounts of cooked mushrooms could be included, e.g., once a week.
2. Serve pulses frequently	Use pulses about twice a week for lunch, and 1–2 times a week for snack meals.	Min. 70–100 g cooked	Additionally, include processed protein-rich plant-based foods, e.g., tofu, or extra pulses every week for lunch or snack meals.
3. Use nuts and seeds frequently	Use nuts and/or seeds every day in lunch or snacks meals.	15–20 g nuts or slightly more [3] and 15–20 g seeds [4]	Include extra amounts of nuts and seeds, including walnuts and chia, known to be rich in n-3 fatty acids.
4. Use plant-based fats often and limit animal fats	Use plant-based fats in the majority of lunch and snack meals. Use animal fats such as butter no more than twice a week.	45–60 g plant-based fats and 4–5 g animal fats	Include oils rich in n-3 fatty acids such as rapeseed oil.
5. Serve mainly whole-grain products and potatoes	Serve starchy foods at all meals. At least half of the grain products should be whole-grain products.	500–650 g grains and potatoes	
6. Serve fish regularly and choose the most sustainable	Serve fish min. once a week for lunch and once a week for snack meals.	50–65 g cooked fish	Not relevant for lacto-ovo vegetarian diet.

Table 4. *Cont.*

Main Guidelines	Frequency of Serving (Plant-Rich Diet) [1]	Average Weekly Serving Amounts at the Child-Care Center per Child (2–4 y) [2]	Additional Considerations for Lacto-Ovo Vegetarian Diet
7. Serve meat in limited quantities and rarely beef	Serve meat once a week for lunch and once a week for snack meals. Beef, veal or lamb can be served once a month.	35–50 g cooked meat [5] including no more than 7–10 g beef	Not relevant for lacto-ovo vegetarian diet.
8. Use dairy products, cheese and egg in moderation	Use eggs once a week or every second week as, e.g., main protein component in lunch meals. Use cheese, e.g., twice a week at lunch and/or snack meals and use dairy products, e.g., 2–3 times a week at lunch and/or snack meals.	20–30 g egg, 20–25 g cheese or 35–50 g (low-fat) dairy products	Use eggs up to twice a week and cheese up to three to four times a week at lunch and/or snack meals.
9. Offer drinking milk and water daily	Offer a small glass of milk every day (milk max. 0.5% fat for 2 y and 1.5% for children 1 y).	4–5 dL milk a week	
10. Follow the season, prefer use of fresh ingredients and limit food waste			

[1] Full portion or more frequently with smaller portion sizes (e.g., buffet style); [2] To be adjusted according to age and appetite; [3] Includes peanuts. For small children, nuts must be ground or served as, e.g., peanut butter. Salt content of nuts and seeds max 0.8 g/100 g; [4] Includes seeds in bread; [5] Meat includes chicken, pork, beef, veal and lamb—cooking loss is included.

4. Discussion

Child-care centers play an important role in children's dietary intake and the environmental impact of the food provided. Through a scenario analysis based on actual purchase data from the City of Copenhagen, this paper demonstrates that it is possible to both improve nutritional content to meet dietary recommendations and at the same time decrease climate impact, without compromising cost (within +5% compared with baseline). Scenario 1 (a plant-rich diet) contained less red meat and animal fats and more dark-green vegetables, nuts, seeds, fish and pulses compared with baseline. Scenario 2 without meat and fish (a lacto-ovo vegetarian diet) further included more processed plant-based protein-rich foods (including soy-based processed products), nuts, seeds and increased amounts of eggs and cheese. This resulted in an estimated decrease in GHGE of 27% and 42%, respectively, for the plant-rich and lacto-ovo vegetarian diets when including carbon opportunity costs. When excluding carbon opportunity costs the reductions were 22% and 36%, respectively.

The reduction potential in GHGE in the present plant-rich diet was less than found by Colombo et al. [38] in an optimized GHGE-reduced (−40%) and nutritionally adequate school lunch menu with 32% less meat and 13% less seafood. This could be seen in the light that there were differences in the composition of the baseline data, e.g., in terms of the red meat content being slightly higher in the Swedish school lunch meals. The City of Copenhagen has already, for several years, worked with sustainable goals for food procurement in terms of increasing the use of organic foods and thereby already decreased the purchase of, e.g., meat and meat products. This may have led to changes in the food and nutritional composition. Studies on food procurement in child-care centers and other public professional kitchens indicate that the meal composition may change as a consequence of a higher degree of organic food procurement to, e.g., cover the price premiums associated with organic food purchase [16]. In a Danish cross-sectional study of 30 child-care centers, it was shown that child-care centers having high organic procurement included more vegetables in the children's hot meals, but the amount varied greatly between centers [39]. However, other factors may influence the reduction potential. Besides having different age groups and therefore different nutrient recommendations for the meals, this study and Colombo et al. [26] made use of another set of GHGE data (the Swedish RISE database), and the content of seafood was decreased and lower in the study by Colombo compared with the present study.

In addition, limiting food waste is critical to improve sustainability and lower GHGE, including optimizing the use of raw products (i.e., using the entire product), adapting portion size/serving bowl size and reusing excess production and leftovers [40].

4.1. Baseline Data

Child-care centers provide meals and snacks to children, covering up to half of children's daily nutrient intake [33,41,42]. In order to ensure the children receive a healthy meal at the child-care centers, it is important that children are offered meals containing sufficient energy and having the right nutritional composition that contributes to their overall diet. In the present study, the estimated amounts of many nutrients were well above the recommendation for planning diets for this target group at baseline. The nutrients that had a lower mean observed density than recommended included vitamin D, calcium and iron. A study by Cuadrado-Soto et al. in Rhode Island (US) likewise found the micronutrient intake density to be adequate for most nutrients among preschoolers across two full days of child care [41]. However, intake of some nutrients was of concern including vitamins D, E, K and potassium [41]. An adequate amount of vitamin D is known to be challenging to reach due to a limited amount naturally available in many food products [32].

Another Danish study examining food consumed for lunch at eight different child-care centers showed that the percent energy from fat (E%) was on average 32 E% and therefore within the recommended range of 32–34 E% [42]. In this study, total fat E% was higher (35 E%). In addition, energy from saturated fat was above the recommended maximum 10 E% (13 E%). This seems to be partly due to a high amount of animal fats being used, in particular butter. For comparison, a Finnish study found that the mean proportion of energy from saturated fatty acids only slightly exceeded the recommendation, i.e., 10.1–10.3 E% for served preschool meals [43].

At baseline, the total meat purchase was 70 g/10 MJ (excluding bones, etc.) and the purchase of fruit and vegetables was 173 and 235 g/10 MJ (in total 408 g/10 MJ), respectively. This is higher compared with values found in a Finnish study investigating three- to four-year-old children's food intake while in preschool. The children consumed 135 g of fruit and vegetables per day, corresponding to 296 g/10 MJ, while the intake of meat/meat dishes (cold cuts, red meat, poultry and sausage dishes) was 87 g/d, corresponding to 286 g/10 MJ [43].

Tovar et al. investigated the nutritional quality of meals and snacks served and consumed in family child care in central North Carolina among children aged 18 months to 4 years [44]. The authors concluded that although family child-care homes were serving few empty calories and various healthy foods, mainly fruit and dairy, there was much room for improvement with regard to vegetables, grains, seafood and plant protein, fatty acids and sodium.

4.2. Plant-Rich Diet

The macronutrient content of the plant-rich diet, as well as the contents of vitamins and minerals, except for vitamin D, were modeled to be adequate according to the NNR recommended nutrient density used for planning diets for groups of individuals aged two to five years.

The amount of meat (raw weight) in the plant-rich diet was 47 g/10 MJ. This makes it possible for the child-care centers to serve one hot lunch meal a week with meat and one hot meal a week with fish. Furthermore, there is room for small amounts of meat and fish in the afternoon snack. The distribution between different fish species was changed toward more mackerel and herring that are lower in climate impact compared with, e.g., shrimps. Colombo et al., however, pointed out that fish production from wild stocks cannot increase much, as a great proportion of the world's fish stocks are already either moderately or fully exploited or over-fished [26].

Purchases of pulses were increased by threefold to 75 g cooked weight per 10 MJ. Moreover, the amount of seeds was increased in the plant-rich diet, and nuts need to be introduced to the meals to a much greater extent. Pulses, together with nuts and seeds, are good sources of protein, dietary fiber, various micronutrients and other bioactive components, and nuts and seeds are also high in unsaturated fatty acids [45,46]. It is suggested to serve pulses about twice a week for lunch and one to two times a week for snack meals and nuts and seeds every day in lunch or snacks. Pulses are the dried seeds of legumes and come in many different shapes, including white and brown beans, dry peas, lentils and chickpeas. Reister et al. [47] emphasized the use of, e.g., chickpeas and suggested chickpeas to be seasoned and served as a side dish, added to casseroles or soups or sprinkled on salads. Similarly, hummus (chickpeas and tahini ingredients) can be served as part of meals like hummus bowls, hummus flatbreads and hummus toasts, offering variety to promote diet quality and health. Nuts must be crushed, ground or served as nut or seed butter (such as peanut butter). It is important to avoid giving whole nuts and similar hard foods to young children to reduce the risk of choking [48].

4.3. Lacto-Ovo Vegetarian Diet

This study is in line with other studies among children showing that the vegetarian diet has a high content of, e.g., dietary fiber, folic acid and vitamin C [49]. Further, the lacto-ovo vegetarian diet was modeled to contain adequate amounts of vitamins and minerals, except for vitamin D, which was found to be especially low in the lacto-ovo vegetarian diet due to the elimination of fish. This makes promotion of vitamin D supplements especially important during months with potential lack of sun exposure. Considerations about how to develop a sufficient and safe fortification program may likewise be relevant. Iodine content was also found to be below recommendation, partly due to no fish being included. In addition, it is possible that the estimated loss of 80% of salt as proposed by Colombo et al. [26] is too high compared with actual practice as the child-care centers in this study only use relatively small amounts of processed foods and therefore might use more salt for food preparation compared with salt that is discarded with, e.g., cooking water. Sufficient intake of iodine in Denmark in general is ensured by mandatory iodine fortification of household salt and salt used as an ingredient in bread and bakery products [50]. Still, attention must be paid to ensure a healthy and nutritious intake in terms of iodine, as well as protein [37], as children may have preferences for and aversions to certain foods, which can contribute to an increased risk of malnutrition [51].

Compared with the plant-rich diet, the lacto-ovo vegetarian diet contains no meat or fish but includes more egg and dairy products, cheese, nuts, seeds, oats and plant-based protein-rich foods, including soy products (particularly tofu and other processed soy-based products). In addition, typically used products in vegetarian diets were added, such as mushrooms due to their aroma properties (e.g., rich in umami substances [52]) and quinoa, known to be rich in protein. It may be important to use processed/cooked mushrooms as they contain smaller amounts of phenylhydrazines than raw mushrooms [36]. In the present study, no replacement of dairy foods with plant-based beverages was made because of the large variation of nutritional properties of these beverages and because inclusion of plant-based beverages has been found to increase costs of the diet [53,54].

Iron content was 6% higher compared with the recommendation. Still, iron may be of particular concern because plant-source foods contain only non-heme iron, which is less bioavailable than heme iron [55], and therefore the choices of foods high in iron should be carefully considered. Some studies in children have demonstrated higher rates of iron deficiency among vegetarians vs. omnivores; others, however, have found no significant difference in iron levels [51]. The presence of vitamin C (besides the presence of animal tissue) in the diet increases the bioavailability of iron. The same effect on the bioavailability of iron and zinc is invoked by, e.g., sourdough leavening because of an increase in the probability of phytic acid breakdown [37].

With regard to protein, because of the lower digestibility of plant proteins, some authors suggest increasing protein dietary reference intake for vegetarian children by 10–15% [56]. However, Mariotti and Gardner state that for children there are no specific concerns regarding protein adequacy because of their high energy requirements compared with those of protein [57]. In the present study, protein content was 86 g/10 MJ, corresponding to 46 g per day. This is well above the recommended 1.1 g protein per kg of body weight per day for food planning purposes, as the average weight of a two- to five-year-old child is estimated to be 16 kg [37].

Vegetarian diets often provide very limited amounts of long-chain n-3 fatty acids. Therefore, a sufficient amount of the essential n-3 fatty acid alpha-linolenic acid (ALA) from plant foods needs to be included in the diet [37]. Important dietary sources of ALA are rapeseed oil, fat spreads made from rapeseed oil, flax seed oil, chia seeds and walnuts [58]. However, ALA is converted to long-chain n-3 fatty acids in limited amounts, and further studies are required to better understand the role of plant-based n-3 fatty acids, how they may play a stronger role in health and the possibility to use algae as a source of long-chain n-3 fatty acids [59].

4.4. Strengths and Limitations

There are several strengths and limitations to consider with regard to both the calculation and the modeling methods used. With regard to the calculation method, many studies have already focused on measuring household food consumption by making use of home food inventories, bar code scanners, food purchase records, supermarket receipts [60] and commercial food purchase data (like GfK) for public health nutrition research [61]. This is, to our knowledge, the first study to monitor a municipality's child-care food purchase data to measure both GHGE and price and nutritional quality of the purchases. The study described a method for analyzing purchase data by compiling complementary information, such as datasets on food nutrient composition and environmental impact assessment. The method takes into account the complexity of food purchase data including individual food characteristics such as preparation waste.

A major strength is that the use of purchase data provides detailed and precise data on food products used and includes information on price and processing level. Price is an important consideration for public meals where budgets are often tightly regulated. Processing level is important in order to be able to estimate more precisely, e.g., nutrient content for pulses where values for cooked and raw pulses are very different. Finally, main guidelines and rules of thumb were made for the transformation of average weekly amounts into practical advice based on serving sizes and frequency of serving across a week. This can provide the basis for translating the nutrient targets into menus, and the rules of thumb are easier to use in everyday life.

The method makes it possible to collect data over an extended period, thereby taking into account seasonal fluctuation, etc. Another strength is that the method has low or no participant burden and is not subject to social desirability bias. It potentially provides a large quantity of data. This, on the other hand, means that it is necessary to consider how the data are best presented, both the dimensions of the foods and beverages and the level at which the data are aggregated. In addition, the method is best suited to be used when there is only one or a few food suppliers, and uncertainties may arise from lack of data from individual smaller suppliers.

Another limitation is that it is not possible to differentiate between food used for different purposes, e.g., for different types of meals. In addition to lunch, most child-care centers in the City of Copenhagen also serve morning and afternoon snacks, and these are important contributors to a healthy diet. Further, the data represent foods purchased, not consumed. This study took into account estimated preparation loss but not serving and plate waste. It is possible that there is a relatively higher waste for some types of products, e.g., some fats being discarded after cooking. However, a study examining food served and consumed for lunch at eight different child-care centers showed that the macronutrient distribution of the consumed food was well predicted by the served food [42].

Two scenarios were presented in the present study, whereas healthy and sustainable diets can be achieved in multiple ways and with a wide variety both across food groups and within food groups. However, the modeled diets only set targets for the larger food groups and subgroups but not the specific types of foods to be consumed. This leaves room for individual choices and options for the child-care centers in order to optimize price, culinary quality, sustainability priorities or nutritional quality.

Finally, the Cool Food Pledge Calculator includes default weighted regional average data for GHGE [31] and thereby does not represent specific Danish values, which for beef and milk are lower [62]. Thus, the GHGE assessment reflects an approximation rather than an absolute with focus on the proportion of reduction. The GHGE database is organized in a way where the values for food-related carbon opportunity costs are separated from the data on the agricultural supply chain. This is a strength since several methods of estimation of GHGE from land-use change (LUC) have been suggested [63–65]. The European PEF guidelines [66] currently suggest not to include LUC in the climate calculations due to the uncertainty of methods and data. The carbon opportunity costs in this study were high, which is why Metrics 2 + 4 may be overestimated compared with other estimates that include LUC. In the present study, calculation of climate impact was based on the edible proportion to take into account food waste due to bones in meat and fish as well as bones purchased for soup/broth in line with World Resources Institute data. This means that the calculation of climate impact was also based on edible amounts of fruits and vegetables, which may cause a small bias due to World Resources Institute data being based on purchased amounts. That said, factors for a given food type can vary widely by production system within regions, e.g., for ruminant meats, such as beef [31], and for fish [67,68]. In the case of the City of Copenhagen, the large volume of organic food being used may affect GHGE values as yields are often lower. On the other hand, organic production has beneficial effects for other sustainability aspects, and increasing organic agriculture may benefit local biodiversity, soil quality and ecotoxicity levels (the toxic effects of pollutants on biological organisms) [31,69].

5. Conclusions

This study provided new knowledge and new methodological insights into how to measure the sustainability and nutritional quality of food purchased within public catering based on large datasets. An advantage of this method is that scenarios were modeled based on actual purchase patterns. A limitation of the study is that only two scenarios were presented, whereas healthy and sustainable diets can be achieved in multiple ways. Future studies should include more scenarios and other settings within public catering having different nutritional requirements, such as older adults. The present study represents the first step in shifting the food purchase for child-care centers in a more climate-friendly direction while improving nutritional content. This was achieved by translating optimal modeled diets to practical application, including main guidelines and rules of thumb for frequency of serving of foods over a week for a plant-rich diet and a lacto-ovo vegetarian diet. These guidelines should be followed by activities that support the kitchen staff in adoption of the diets. This may include implementation of relevant tools like menu planners, new recipes using plant-based ingredients, education activities and food product innovations, as well as the promotion of healthy and sustainable foods among customers using nudges, information, etc. Further, child-care centers may act as a channel to introduce and inspire parents to cook healthy plant-rich meals at home. In addition, follow-up measurements should be carried out in order to follow progress and target future initiatives. These kinds of initiatives have the potential to significantly affect the transition toward a more healthy and sustainable food system.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13105551/s1, Table S1: Overview of the organization of food group and subgroup categorizations of food items purchased and estimated food waste and cooking yield/loss for raw products.

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